This measure of output is reasonable and appropriate, even though it does not reflect shifts in lengths of haul or times of day at which calls are made. Access charges are the largest component of switched services cost, and access charges depend solely on minutes of use. Also, modern technology has made costs much less sensitive to distance.[14] Finally, cost differences between day and evening services have declined from historical levels, since many facilities now peak during evening hours.[15] For these reasons, we believe that CL minutes are an adequate output measure for our purposes.

CL access is used at both ends of domestic message toll calls. It is used at one end of unidirectional calls (e.g., WATS or 800 service) or international message toll calls. It is not used at all for private line services that are closed at both ends; e.g., connecting two corporate locations.

Only part of AT&T's interstate costs are attributable to switched services. In our analysis, we attribute interstate costs to switched versus nonswitched services on the basis of switched versus nonswitched revenues.[16] Switched revenues include: (domestic plus international) duodirectional revenues[17] plus half of unidirectional revenues[18] less half of international message toll revenues. This measure includes all revenues of services which use CL access at both ends, half of revenues for services which use CL at one end, and no revenues from services that are not switched at either end. These revenues correspond precisely to our measure of quantity of switched services; namely, CL minutes. Switched services revenues (less CL expense) were 63 percent of AT&T's total interstate revenues (less

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[14] While the cost of fiber optic transmission systems remains distance-sensitive, the fraction of the total costs (including access, billing and collection, G&A, network) of a long-distance call flowing from transmission has shrunk markedly over the last decade. Carrier tariffs have reflected this development, becoming almost completely distance-insensitive inside the United States.

[15] Indeed, according to AT&T data, evening revenues, even at reduced rates, have exceeded day revenues in recent years.

[16] Costs attributions are proportional to revenues, after common-line costs are subtracted from both. This procedure is discussed below.

[17] This category includes message toll service and the PRO Family of offerings. PRO services are a group of message services that are offered with various quantity discounts.

[18] This category includes all WATS and 800 services plus switched services, such as Megacom and Software-Defined Networks, that are designed for large customers.

CL expense) in 1985. This ratio rose slightly to 64 percent in 1988. It then increased sharply, rising to 70 percent in 1991.[19]

Figure 1 shows AT&T's switched output from 1985 to 1991. Output grew steadily during the entire period at an average rate of 7.3 percent per year. Growth was 7.9 percent per year from 1985 to 1988 and 6.8 percent thereafter.[20] Access price reductions, which were passed on to interexchange customers, and the general economic recession contributed to the more rapid growth during the earlier period.

C. Input Indices

Changes in input quantities are calculated by examining the *real* change in input expenditures. Subtracting the changes in prices of inputs removes effects that are attributable to shifts in factor prices, rather than increased input quantity.[21] In calculating the growth of inputs, we used the standard procedure of weighting various components by their share of total cost. We use a four-factor model which includes the three traditional inputs of labor, MRS (materials, rents and services), and capital; and an additional factor to reflect the costs of access. Real expenditures for each of the four input factors were multiplied by the respective contribution to overall input expenditures. The total reflects growth (or shrinkage) in total input quantity which must be subtracted from the growth in total output quantity to reveal changes in productivity. The input variables are discussed in detail in the following text.

1. Access Costs

We used the growth rate of CL switched access minutes as our index of access inputs. Access costs include both CL and traffic sensitive (TS) costs used to provide the

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[19] Nonswitched services are consumed primarily by large business and governmental customers. Competition for these customers is intense. Consequently, profit margins for nonswitched services are probably smaller than those for switched services. If so, our procedure for attributing costs probably attributes too much cost to switched services and not enough costs to nonswitched services.

As stated above, the fraction of switched services rose only slightly from 1985 to 1988, but increased sharply thereafter. Hence, our procedure attributes *slightly* too much cost gain to switched services from 1985 to 1988 and *significantly* too much cost gain thereafter. The overall effect is to underestimate the difference in productivity gains between the two periods. In this regard, our methodology probably yields a conservative estimate of the productivity gains resulting from price caps.

[20] Growth rates from 1985 to 1988, cited throughout this study, were derived by first determining the percentage changes from 1985 to 1986, from 1986 to 1987, and from 1987 to 1988. Geometric averages of the three percentage changes were then calculated. Growth rates during the price-cap period were similarly calculated using 1988 through 1991 data.

[21] As discussed below, this operation is unnecessary for access, which is measured in physical units.

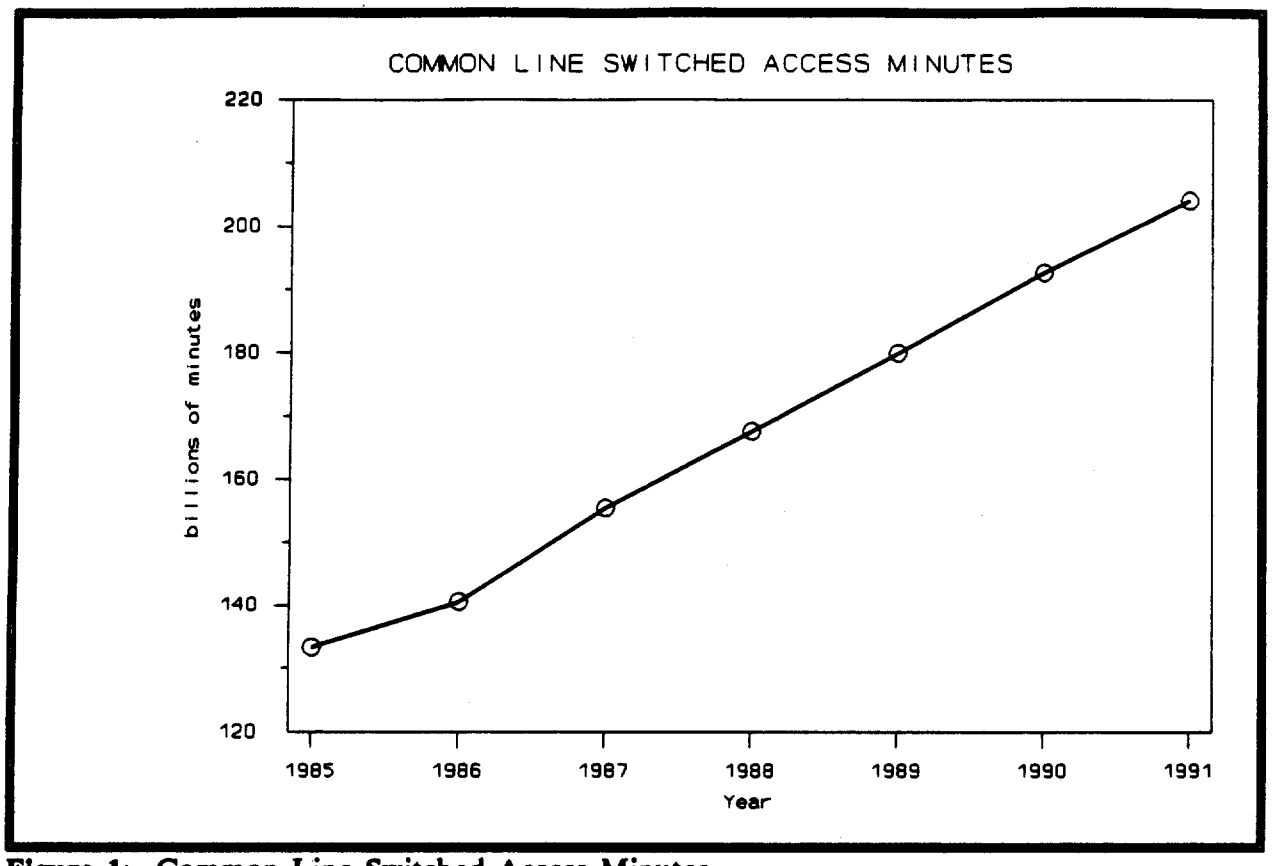

Figure 1: Common Line Switched Access Minutes

output we are analyzing.[22] By definition, AT&T's switched access expenses grew at the same rate as output; namely, an average of 7.3 percent per year.

2. Noncapital Costs

Noncapital costs consist of operating expenses less access, taxes, and depreciation. Interest expense is not included, since it is not an operating expense. In some years, AT&T's financial reports include expenses (e.g., payments to induce employees to retire early) that

[22] In this calculation, the TS expense attributable to switched output is the TS price times number of CL minutes. Remaining TS minutes—those attributable to closed end of WATS—are not included. They are attributable to the nonswitched half of the unidirectional output.

do not reflect solely the costs of providing output in that year. We made additional adjustments so that these charges do not bias our productivity analysis.[23]

Adjusted noncapital expenses were separated into quantities of labor and MRS using ratios derived from total company (interstate plus intrastate) data. To derive our quantity indexes for noncapital inputs, we multiplied labor and MRS by a conversion factor to approximate the portion of noncapital costs pertaining to switched services.[24]

Labor expenses were deflated using a price index developed from the "Nonsupervisory-Worker Average Hourly Earnings for Telephone Communications" data series published by the Bureau of Labor Statistics.[25] This deflator is ideal, since it is narrow enough to reflect conditions in the telecommunications industry, but broad enough not to be dominated by AT&T (see footnote 11).

MRS expenses were deflated by the gross national product fixed-weighted price index (GNPPI). This deflator is appropriate, since MRS consists of the outputs of a wide range of industries. GNPPI is the same index that the Commission uses to reflect inflation in adjusting the price-cap formulae for AT&T and LECs.

AT&T's real noncapital expenses for switched services are shown in Figure 2. Over the whole period, noncapital inputs remained relatively constant. However, this conceals distinctive differences between growth from 1985 to 1988 and growth thereafter. Noncapital expenses increased an average of 3.0 percent per year in the earlier time period and declined 3.0 percent per year during the later time period. This analysis is particularly noteworthy as it reveals an underlying cause for AT&T's post-1988 productivity gain. As Figure 2 illustrates, AT&T made deep cuts in labor and MRS costs in 1989 through 1991. These large reductions in inputs led to high productivity growth.

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[23] In making these adjustments, we relied on data provided by AT&T from its financial records. Adjustment were made in 1988, 1990, and 1991. The 1988 adjustment primarily reflects transitional costs associated with AT&T's retirement of analog plant (discussed below). The 1990 adjustment reflects primarily transitional costs associated with early retirement of employees. The 1991 adjustment reflects primarily accounting changes associated with pension and employee benefits, rents, and payables and receivables. In total, these adjustments are roughly equivalent to an annual cost of $200 million. We, therefore, added $200 million (real) to each year's costs (1985 through 1991) to reflect the occasional need for such one-time adjustments. The last adjustment has little effect on our estimate of year-to-year productivity gains.

[24] This conversion factor equalled the ratio of switched revenues less CL costs to total service revenues less CL costs. Adjustments to the conversion factor were necessary for 1985 and the first five months of 1986, during which WATS used CL access at the closed end, as well as the open end.

[25] The data were adjusted to reflect fringe benefits, as well as wages and salaries.

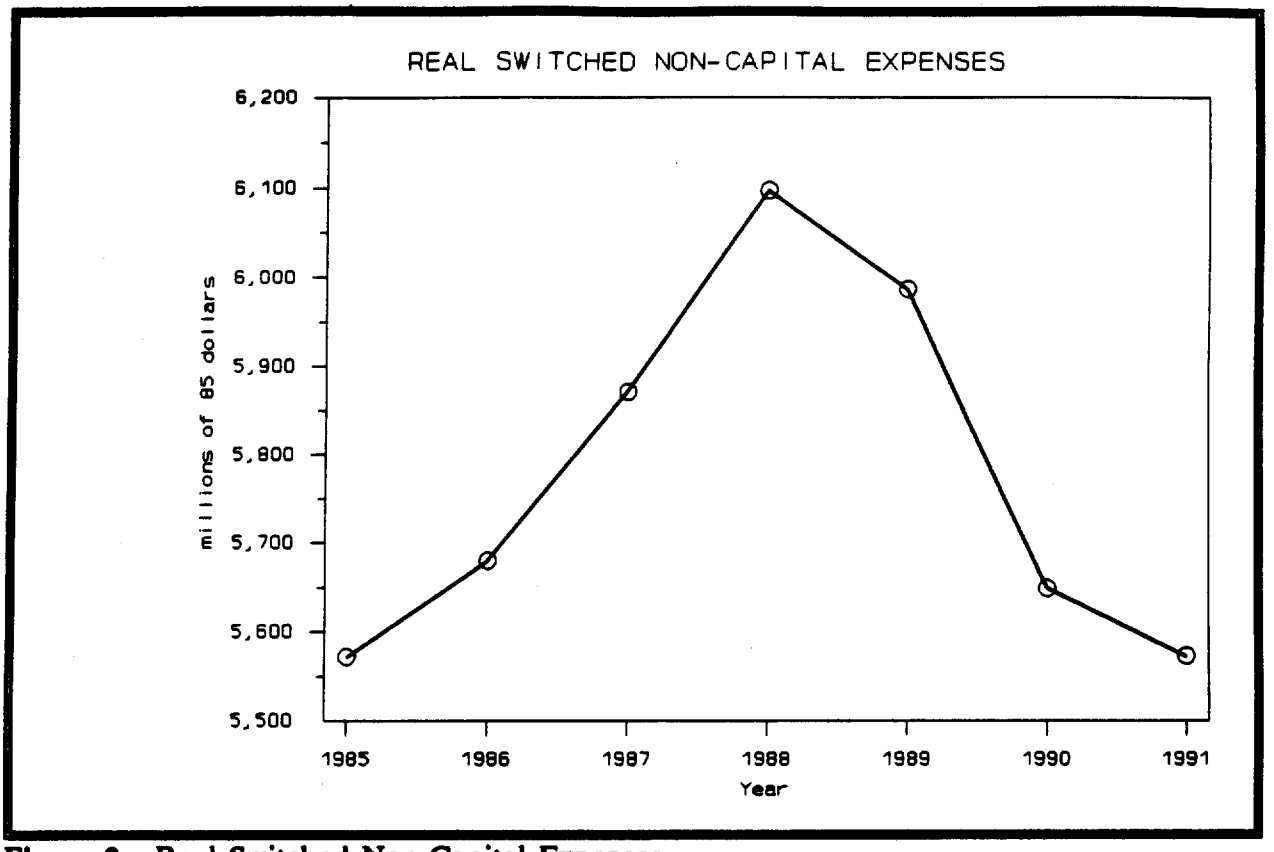

Figure 2: Real Switched Non-Capital Expenses

3. Capital Costs

Capital costs consist of return to capital (both interest and return to stockholders), as well as depreciation and taxes. Capital costs are expressed as the quantity of capital times an annualizing factor that converts capital (measured in dollars) to an annual charge (measured in dollars per year).

Plant modernization during the period profoundly affected AT&T's capital costs. Beginning around 1989,[26] AT&T aggressively modernized its plant, replacing older analog equipment with modern digital equipment. This modernization was necessary to respond to competitors who were touting their state-of-the-art networks. In 1988, AT&T took a $6.7 billion write-off associated with accelerated digitization program costs.[27]

The impact of AT&T's modernization program can be clearly seen in Figure 3, which shows the portion of the interstate rate base attributable to switched services. That

[26] The modernization program actually began earlier, but 1989 is the first year that the large capital investments appeared on the books.

[27] AT&T 1988 Annual Report, p. 27.

rate base grew at 2.6 percent per year from 1985 to 1988. It grew $985 million (1985 dollars) or 17.0 percent from 1988 to 1989. It continued to grow by 1.0 percent per year from 1989 to 1991.

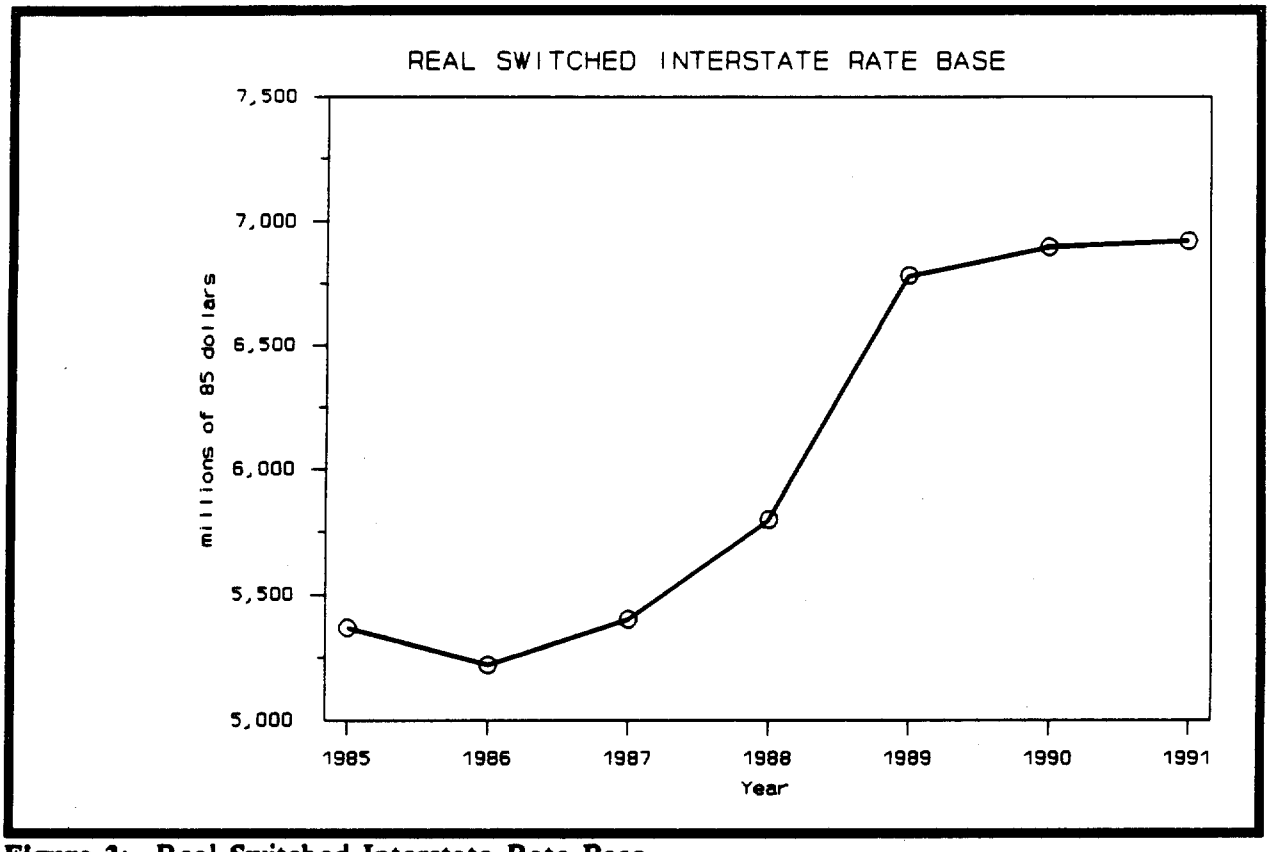

Figure 3: Real Switched Interstate Rate Base

To derive our quantity index for capital inputs, we multiplied capital costs by a conversion factor to approximate the portion of capital costs pertaining to switched services.[28] Capital costs were deflated by the Bureau of Labor Statistic's producer price index for telephone and telegraph apparatus. A producer price index is appropriate for purchases of capital equipment. As before, the index reflects conditions in the telecommunications industry, but it is not dominated by purchases of AT&T Communications.

In our analysis, we assume a real rate of return of 8.29 percent per year. This real return to capital equals AT&T's nominal rates of return less inflation rates averaged

[28] The conversion factors were calculated as described in footnote 24.

from 1985 through 1988. The real (as opposed to nominal) return to capital is the appropriate measure and it is generally used in productivity studies.[29]

In productivity studies capital is appropriately valued at its economic value.[30] That value can differ substantially from book value, especially in regulated industries, where book depreciation is determined in a political process that may not reflect underlying economic conditions. Our treatment of economic value and economic depreciation is described in detail in the Appendix.

Figure 4 shows AT&T's real economic capital during the period 1985 to 1991. Real economic capital, like book capital as shown in Figure 3, grew modestly from 1985 to 1988 and sharply thereafter. However, the growth of economic capital is somewhat smoother. Average growth was 0.7 percent per year from 1985 to 1988 and 10.9 percent per year thereafter.

Figure 5 shows AT&T's capital costs during the period. These costs grew 4.3 percent per year from 1985 to 1988 and 6.1 percent per year thereafter. During the 1985 to 1988 period, the stock of economic capital grew relatively slowly, but there were substantial costs of economic depreciation, as the older analog plant declined rapidly in value. During 1989 to 1991, capital grew more rapidly, but the rate of economic depreciation was lower.[31] The behavior of economic depreciation contrasts sharply with that of *book* depreciation, which was higher during 1989 to 1991 than 1985 to 1988.

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[29] The reason is that investments in plant or equipment yield capital gains on that plant or equipment (measured in nominal terms). The actual cost of capital is the difference between what is paid for the use of the capital (the nominal cost of capital) and the capital gains (approximated by the inflation rate).

[30] For example, see Michael Denny, Melvyn Fuss and Leonard Waverman, *op. cit.*, p. 217.

[31] In general, one would expect economic capital costs to be a smoother time series than accounting cost measures. The latter are subject to shocks (e.g., the 1988 write-off) when changes in economic conditions are recognized on the books of the company. Economic capital costs include adjustments every year for changing economic conditions.

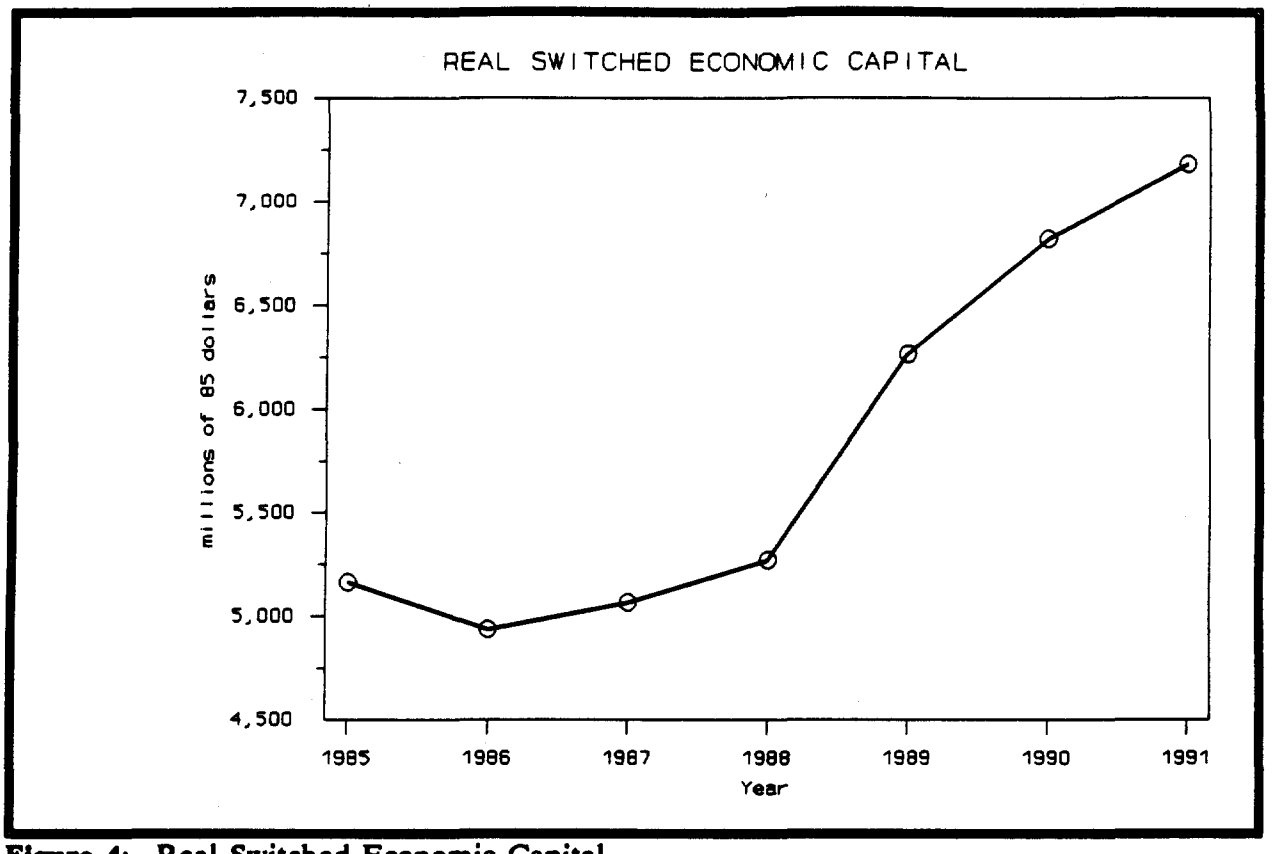

Figure 4: Real Switched Economic Capital

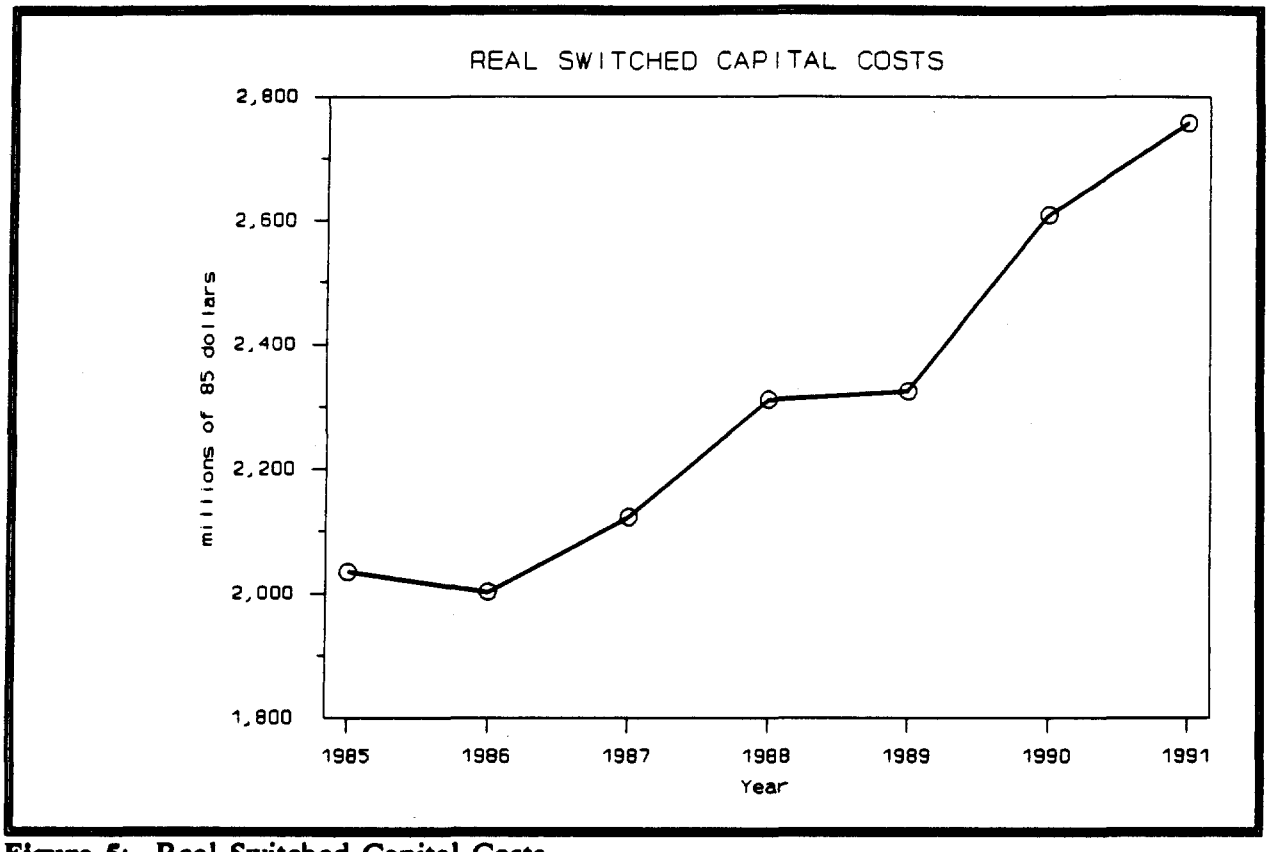

Figure 5: Real Switched Capital Costs

IV. PRODUCTIVITY GROWTH

To determine the effect of price-cap regulation on productivity growth, we examined the difference in productivity under ROR regulation and price-cap regulation. Using the foregoing methodology we estimated that cumulated productivity gains were $1.8 billion greater during the years 1989 to 1991 than during the years 1986 to 1988.[32]

This estimate is based on our four-factor model of total output. One could alternatively use a three-factor model of AT&T's value-added over and above access. This approach is reasonable, since switched access is used in fixed proportions to produce switched output. Under that model, the cumulative gains from price caps were also $1.8 billion. Thus, the two models yield the same estimate to two significant digits (though the estimates are not identical).

A. Timing of Productivity Gains

Most of the productivity gains in the price cap period occurred early in that period. The general economic recession that began in mid-1990 undoubtedly contributed to the slowdown in productivity growth. However, there are also reasons why one would, *a priori*, expect *precisely* this pattern of productivity gains in a four-year price-cap plan:

- Such a plan offers maximal incentives to improve efficiency the first year, since the company can begin to enjoy the benefits immediately and enjoy the benefits of productivity improvements for the entire four years.

- In addition, some of the productivity gains of price caps may be transitional. Initially, there are many opportunities for productivity improvement. These opportunities accumulated over decades of ROR regulation with dull efficiency incentives. When incentives are sharpened, the firm can take advantage of the "stockpile" of accumulated opportunities for productivity improvement. The resulting transitional gains may exaggerate the long-run productivity effects of price caps. Principles of diminishing marginal returns suggest that during the transition the easiest, least costly, and most significant productivity and innovation agains would be accomplished first. Subsequent gains become harder and harder to achieve.

B. Quality of Service

These estimates of productivity do not take quality into account. In reality, the quality of AT&T's service significantly improved during the period, as a result of its

[32] In making this comparison, we multiplied the earlier productivity gains by the ratio of switched revenues in 1988 to switched revenues in 1985. This adjustment makes dollar productivity gains comparable in the two periods.

conversion from analog to digital.[33] The customer benefit of the improved quality is a productivity improvement that goes beyond the productivity gains that we estimate.[34]

C. Demand Growth

In assessing the gains from price caps, we must also consider other factors that affected productivity differently in 1986 to 1988 than in 1989 to 1991. The two major factors to consider are access charge reductions and the general economic recession. Both these factors affected growth of demand.

1. Access Charge Reductions

During the entire post-divestiture period, the FCC has pursued a policy of reducing access charges. This policy was carried out by instituting subscriber line charges and reforming state-federal cost allocations. The larger gains from this program occurred in the 1986 to 1988 period, during which switched access charges declined by 2.88 cents per access minute. Access cost reductions in 1989 to 1991 averaged only 1.72 cents per access minute.

Access cost reductions lead to demand stimulation when interexchange carriers pass the savings in access costs on to their customers in the form of lower prices.[35] This has occurred both under ROR regulation and under price caps.[36]

2. General Economic Recession

Gross Domestic Product (GDP) in real terms grew 3.3 percent per year from 1985 to 1988. Because of the recession, the economy as measured by GDP grew only 0.9 percent

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[33] Sprint launched an aggressive national advertising campaign, emphasizing the high quality of its all-fiber, digital network. AT&T rapidly responded by upgrading its network, taking a $6.7 billion write-off in the process. These developments highlight the importance of quality in marketing interexchange telecommunications.

[34] Our methodology takes into account capital costs (e.g., economic depreciation) associated with quality improvements. It does not, however, include consumer surplus deriving from quality improvements.

[35] Recent demand studies have estimated long-run price elasticities of approximately -0.7. See J. P. Gatto *et al.*, "Interstate Switched Access Demand Analysis," in *Information Economics and Policy*, Vol. 3, No. 4, p. 344.

[36] Even without regulation, competitive pressures would cause access charge reductions to be passed on to customers. In a purely competitive or contestable market, all access charge reductions would be passed on.

per year thereafter.[37] The recession had a negative effect on demand for AT&T's services,[38] as well as for goods and services generally.

3. Effect of Slower Demand Growth

Largely because of slower declines in access charges and the recession, AT&T's demand grew less rapidly under price caps (6.8 percent per year) than from 1985 to 1988 (7.9 percent per year). When demand growth slows, firms often have excess capacity in the short run and cannot utilize fixed assets effectively. Consequently, *other things being equal*, one would have expected greater productivity gains in 1986 to 1988 than in 1989 to 1991. In actuality, AT&T's productivity gains were, on average, *greater* during the price-cap period than under rate-of-return. This implies that the true effects of price-cap regulation were even greater than our estimates, which are biased downward by the effects of slower demand growth.[39]

AT&T's productivity gains in 1989 through 1991 are more striking when contrasted to productivity gains of the general economy. While AT&T's productivity gains remained substantial throughout the period, productivity gains for the private business sector became *negative* during this time period; the general economy became *less* productive.[40]

D. Effect of Price Caps

We conclude from the above discussion that productivity gains attributable to the deployment of price caps probably substantially exceeded $1.8 billion. In addition to yielding the observed cumulative productivity gains, price caps overcame the negative effects of slower reductions in access charges and the recession.

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[37] *Survey of Current Business*, Federal Reserve Board, "Gross Domestic Product in Constant Dollars": Table 2, February 1992, p. 32 and Table 1.2, March 1992, p. 5.

[38] Recent demand studies for interexchange telecommunications have estimated long-run income elasticities of approximately 0.8. See J. P. Gatto *et al.*, *op. cit.*

[39] Our procedures provide an estimate of the productivity gains that actually occurred. We do not, however, know how much worse productivity growth would have been during 1989 to 1991 (compared to 1986 to 1988) if traditional ROR regulation had continued.

[40] See the Department of Labor, Bureau of Labor Statistics' Multifactor Productivity Measures for the private business sector. Negative overall measures of productivity growth largely reflect the cyclical effects described above.

V. WHO BENEFITTED FROM THE EFFICIENCY GAINS?

We have estimated that price caps resulted in cumulative productivity gains of more than $1.8 billion—over and above those of the productivity gains prior to price caps. We now consider how efficiency gains were distributed across the economy. Who reaped the benefits?

We begin our analysis by developing a characterization of the model that the FCC developed for administering price caps. We then compare that model to actual experience under price caps. The analysis shows that customers have substantially benefitted under price caps in ways that are not envisioned in that model.

A. A Characterization of the FCC's Price-Cap Model

In establishing its price-cap formulae, the FCC intended that AT&T and its customers would share the efficiency gains resulting from AT&T's sharper incentives. Customers would receive the consumer dividend. AT&T would benefit to the degree that its actual productivity gains exceeded historical levels plus the consumer dividend. Table I presents a characterization of the FCC's price-cap model as applied to switched services.[41]

The upper part of the table pertains to the demand side of the market. The first line is growth of GNPPI. The entry, 4.3 percent per year, is the actual rate at which GNPPI grew in 1989 to 1991.

[41] The FCC first revealed its model in the NPRM (1987). It then continued to refine the model in the FNPRM (1988) and the SFNPRM (1989).

Table I

A Characterization of the FCC's Price-Cap Model
Interstate Switched Services

Item	Percent of Switched Revenues Net of Access	
Customer Benefit		
1. Increase in GNPPI (Data)	4.3%	
2. Less historical efficiency gains (FCC-determined)	-2.5%	
3. Price increase: historical efficiency (Line 1 less Line 2)	1.8%	
4. Less consumer dividend (FCC-determined)	-0.5%	} Projected customer benefit
5. Change in tariffed rates (Line 3 less Line 4)	1.3%	
AT&T Benefit		
Projected increase in AT&T's profits (Hypothetical)	0.5%*	} Projected AT&T benefit

* This number corresponds to an increase of approximately 77 basis points each year in AT&T's rate of return.

The next line shows historical efficiency gains, which the FCC determined (optimistically) to be 2.5 percent per year.[42] "Efficiency" gains, as shown in this table, must be carefully distinguished from "productivity" gains. The latter are based on analysis of economic concepts, such as economic value and economic depreciation. Productivity gains, such as estimated in the above sections of our study, cannot be directly used to compute price changes in a regulatory setting. Any regulatory plan, including price caps, must give the firm the opportunity to recover and earn a fair return on prudently invested capital.[43] The FCC and most state regulatory commissions implement this court-imposed standard using the "original-cost" approach.[44] Under that approach, the company is allowed to recover its costs, including *book* (not economic) depreciation. Those prices must also give the company the opportunity to earn a fair return on the *book* (not economic) value of prudent investments.

The third line of the table is the difference of the first two. It indicates how much prices would have increased (on average, net of access price reductions) if efficiency gains had continued at historical levels and *book* profitability remained at historic levels.

The fourth line is the "consumer dividend," which the FCC set at 0.5 percent per year.[45] In the FCC model, this is the projected customer benefit of price caps. Subtracting the consumer dividend from the third line, we obtain the *actual* increase in average tariffed rates allowed under the FCC plan.

The lower half of the table shows the projected increase in AT&T's profits. The FCC contemplated that AT&T's profits would increase. Indeed, the whole point of price caps is to provide efficiency incentives through profit opportunities. However, the Commission never indicated how much they expected AT&T's profits to increase. In the table, we chose the entry of 0.5 percent per year so that the benefits to AT&T would equal the customer benefit embodied in the consumer dividend.

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[42] The FCC's analysis indicated that historical efficiency gains were only 2.3 percent per year. If that analysis is correct, the consumer dividend in the price-cap plan is actually 0.7 percent per year. See FCC, *SFNPRM*, pp. 103-125 and Appendix E.

[43] This principle has been established by the courts. For example, see *Bluefield Water Works & Improvement Co. v. Public Service Commission of West Virginia* (262 U.S. 679, 1923) and *Federal Power Commission v. Hope Natural Gas Company* (320 U.S. 391, 1944).

[44] The alternative, used by some state commissions, is the "fair-value" approach.

[45] Under the FCC plan, 1.3 percent is obtained by subtracting the historical efficiency gains (2.5 percent per year) and the consumer dividend (0.5 percent per year) from the GNPPI (4.3 percent per year).

In order to reap half the efficiency gains from price caps, AT&T would have needed to increase its rate of return by 77 basis points per year.[46] The resulting rates of return would have been as follows:

- 1988: 12.48 percent per year (actual)
- 1989: 13.25 percent per year (projected)
- 1990: 14.02 percent per year (projected)
- 1991: 14.79 percent per year (projected)
- 1992: 15.56 percent per year (projected)

The rate of return must grow cumulatively in order to equal the consumer dividend, since the consumer dividend also grows cumulatively; i.e., prices in the first year are 0.5 percent lower than base prices; prices in the second year are 1.0 percent lower than base prices; and so forth. Of course, AT&T would have had to achieve large cumulative efficiency gains in order to earn the above returns.

In actuality, AT&T has not been able to earn rates of return anywhere near as high as the numbers listed above. Consequently, as discussed below, customers have reaped the lion's share of the benefits from price caps.

The FCC model, as characterized in this section, is based primarily on the parameters of the FCC's actual price-cap plan. We have, however, made a specific assumption about how the productivity gains from price caps are divided between AT&T and its customers; *viz*, 50/50. Table I can be modified to reflect alternative assumptions regarding that division.

B. Actual Price-Cap Experience

Our characterization of the FCC's price-cap model can now be compared with actual price-cap experience, as illustrated in Table II. The first four lines of Table II are the same as in Table I. The fifth line is the customer benefit that resulted from AT&T's voluntarily pricing below the price caps.[47] The sixth line is "customer migration," the process by which customers substitute lower-priced services for higher-priced ones. Customer

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[46] The interstate rate base attributable to switched services is approximately 65 percent of switched revenues less switched access expense. We divide 0.5 percent by percent 65 percent to get 77 basis points.

[47] Customer benefits from below-cap pricing were estimated as follows: Price-cap revenues for each service category on July 1 of each year were multiplied by the difference between the July 1 price-cap index and the July 1 actual price index. The sum of these products (across all switched services) was divided by the sum of price-cap revenues (across all switched services). This quotient was then multiplied by switched revenues net of access for each year.

migration during the price-cap period largely took the form of customers' moving to SDN. In addition, AT&T was subject to intense competitive pressure as its rivals began to offer customized services to large customers. AT&T responded by aggressively deploying Tariffs 12, 15 and 16.

Customer migration applies primarily to domestic services. International message toll service (IMTS) accounts for almost all international switched traffic. We therefore estimated the combined effect of below-cap pricing and customer migration as the difference between the decline in average revenues of domestic switched services less the decline in the tariffed price of domestic switched services.[48] The difference is expressed as a percent of AT&T's domestic plus international switched revenues (net of access).

As a result of customer migration, the prices *paid* by AT&T's customers fell more rapidly than the prices *charged* by AT&T for the initial mix of services (prior to migration). Consequently, the revenue that AT&T receives per minute of traffic is reduced—apart from any reductions in tariffed rates. The effects of customer migration resemble those of tariff reductions. Customers benefit by reducing their expenses for telecommunications. AT&T must have productivity gains to offset the lost revenues, or its profitability will decline. We

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[48] During the price-cap period, IMTS rates fell by approximately the same percentage as the price-cap index in basket 1. Consequently, domestic services could fall at approximately the same rate and meet the price-cap constraint. We can, therefore, estimate the combined effect of below-cap pricing and customer migration as the difference between the change in average price (net of access) *paid* for switched service with the price change indicated by GNPPI - X (1.3 percent per year).

Our previous estimate of switched revenues includes half of IMTS revenues. We subtract out these IMTS revenues to obtain domestic switched revenues.

We also subtract IMTS minutes from CCL minutes. We have data on international conversation minutes, both United States and foreign billed. We divide the sum of United States and foreign minutes by 0.95 to convert conversation minutes to access minutes; 0.95 is the ratio of average conversation minutes to average terminating access minutes for the years 1989 to 1991.

During the price-cap period, the average price (net of access) *paid* for domestic switched services declined by 0.4 percent per year. At the same time, GNPPI - X was +1.3 percent per year. This corresponds to domestic below-cap pricing and customer migration of 1.7 percent per year; i.e., the difference between +1.3 percent and -0.4 percent.

The next step in our calculation is to multiply 1.7 percent by 0.88, which is the fraction of domestic switched revenues (net of access) to total switched revenues (net of access). This yields our estimate of the combined effect of below-cap pricing and customer migration of 1.5 percent per year, which is expressed as a fraction of total switched revenues (net of access).

Finally, we estimate customer migration as the difference between this combined effect and the customer benefit of below-cap pricing, as estimated in footnote 47.

estimate that customer benefits from migration for switched services amounted to $600 million during the 1989 to 1991 period.

Table II

Actual Price-Cap Experience
Interstate Switched Services

Item	Percent of Switched Revenues Net of Access	
Customer Benefit		
1. Increase in GNPPI (Data)	4.3%	
2. Less historical efficiency gains (FCC-determined)	-2.5%	
3. Average price increase: historical efficiency (Line 1 less Line 2)	1.8%	
4. Less consumer dividend (FCC-determined)	-0.5%	
5. Less pricing below cap (Data)	-0.6%	Actual customer benefit: 2.0%
6. Less customer migration (Data)	-0.9%	
7. Increase in price actually paid (Line 3 less Lines 4, 5 and 6)	-0.2%	
AT&T Benefit		
Increase in AT&T's profits (Data)	0.2%*	} Actual AT&T benefit

* This number reflects the annual growth rate of AT&T's actual profits between 1988 and 1991. The number in the table corresponds to an increase of approximately 31 basis points each year in AT&T's rate of return.

The bottom part of the table shows that the increase in AT&T's profits equaled 0.2 percent of the difference between switched revenues and switched access expense.

The benefits to customers, discussed above, were 10 times as great as this benefit to AT&T. Customer benefits, including historical productivity growth, were more than 20 times the benefit to AT&T.

VI. CONCLUSIONS

We compared the growth of AT&T's productivity under price caps with that prior to price caps. We found that during the price-cap period, AT&T reversed the previous upward trend in real noncapital costs (labor, materials, rents and services). AT&T also thoroughly modernized its network, replacing antiquated analog equipment with digital equipment. Overall, the cumulative productivity gain was $1.8 billion higher during the price-cap period 1989 to 1991 than during the period 1986 to 1988.

That difference is a conservatively low estimate of the gains from price caps. For one thing, AT&T's quality of service improved, as it retired virtually all its analog plant. In addition, demand grew more slowly in 1989 to 1991, because access charges did not decline as much and because of the general economic recession. Slower demand growth would have tended to *lower* productivity growth if the regulatory regime had remained the same. Finally, our estimates do not include productivity gains associated with nonswitched services, which account for about 30 percent of AT&T's interstate revenues.

Our study has important policy implications regarding the renewal of AT&T's price-cap plan:

- Price caps have been a big success in increasing efficiency and promoting consumer welfare.

- During the price-cap period, customers benefitted by paying lower prices for interexchange services. AT&T benefitted from increased profits. The customer benefits, apart from historical productivity growth, were 10 times the benefit to AT&T. The customer benefits, including historical productivity growth, were over 20 times the benefit to AT&T. Reducing AT&T's share of gains below this level could impair the incentives that led to the gains in the first place.

- Because price caps have been so successful, the Commission should seriously consider further regulatory reform that would sharpen AT&T's efficiency incentives even more, and it should avoid actions that would blunt those incentives.

ECONOMIC VALUE AND DEPRECIATION

The economic value of telecommunications plant may be defined as the lesser of: (1) the cost of replacing the capital with latest technology that can perform the same functions; and (2) the present value of the quasi-rents (i.e., profits, disregarding the costs of sunk capital) that the capital can be expected to produce. The second part of the definition applies to plant whose function is obsolete. In such cases, the economic value of the plant is less than replacement cost.

The distinction between economic value and book value is especially important in analyzing AT&T's productivity in the post-divestiture period. In particular, we must carefully model the effects of AT&T's conversion from analog to digital plant.

In economic terms, the economic value of the analog plant began to decline rapidly around 1985, when the interexchange industry started to deploy fiber optics on a large scale.[1] Our analysis reflects that fact. The alternative approach, treating the 1988 write-off as a cost of doing business in 1988, is obviously not appropriate for productivity analysis. In our study, it would lead to unreasonably *high* estimates of productivity gains from price caps. Taking account of economic valuation is both more accurate and more conservative.

In the regulatory process of determining allowed depreciation, expected mortality functions for plant are developed. In our analysis, we reason that book values would be acceptable proxies for economic values if expected retirements of plant, as indicated by regulatory mortality functions, were accurate.[2] In reality, the mortality functions used in 1985 did not anticipate the rapid retirements associated with AT&T's modernization beginning around 1989. Hence, book values during 1985 through 1988 exceeded economic values.

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[1] An investment of $6.5 billion by the industry into fiber backbone facilities expanded the total number of route miles 375 percent between 1985 and 1991. AT&T's portion of this investment, $2.6 billion, led to a 549 percent increase in AT&T's route miles during this time period. See J. M. Kraushaar, "Fiber Deployment Update," Industry Analysis Division, Common Carrier Bureau, Federal Communications Commission, March 1992.

[2] Under these circumstances, book value would approximately equal economic value under "fair" ROR regulation. See Richard Schmalensee, "An Expository Note on Depreciation and Profitability under Rate-of-Return Regulation," *Journal of Regulatory Economics*, Vol. 1, No. 3, September 1989, pp. 293-98.

We estimate economic value by making adjustments to book values. In particular, we compare actual retirements of embedded 1985 plant[3] with the slower rate of retirement envisioned in the 1985 regulatory mortality functions.[4] We then calculate the loss of capital services caused by these early retirements.[5]

We then use a sinking fund schedule to amortize this loss over the four years 1985 to 1988. This procedure levels the total capital charges (return to capital plus taxes plus depreciation); so the timing of depreciation does not affect our estimate of productivity during that period. Since AT&T had installed much of its new digital plant by 1989, extending the amortization period that far would be inappropriate. The result would be to include in 1989 capital charges for both the new plant and the old plant that it replaced. That procedure would clearly lead to an overestimate of economic cost of capital in 1989.

For plant of vintages 1986 to 1991, we assumed a constant rate of economic depreciation. We applied that same constant rate to 1985 plant that was not retired between 1985 and 1991. This depreciation rate, unlike linear depreciation rates, applies to the undepreciated value of the plant—not the original cost.

We chose a constant rate of economic depreciation so that our estimate of economic value on January 1, 1991 was close to gross book value of plant less the depreciation reserve that AT&T recommended to the FCC. The depreciation rate that worked best was 18.5 percent per year. Subject to that rate, economic value on January 1, 1991 was $9.9 billion. At that time gross book value less AT&T's recommended reserve was approximately $9.9 billion.[6] The rate base (gross book value less book depreciation) was

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[3] This plant consists of plant of 1985 vintage and all earlier vintages. This analysis is based on data on AT&T's Interstate Division.

[4] We do not have data on scheduled retirements beyond 1991. We estimated that schedule as a proportional extension of actual retirements that occurred between 1985 and 1991.

[5] This calculation is based on a discount rate of 16.53 percent per year which includes return to capital and taxes. The value of capital services is scaled so that the total value of the services is the original cost of the plant that was retired times the 1985 ratio of net plant to gross plant.

[6] This estimate is based on an analysis of the AT&T Interstate Division.

$11.2 billion.[7] A high economic depreciation rate is necessary in order to reflect the rapid obsolesence of modern telecommunications equipment.

[7] Our estimates of productivity gains are not sensitive with respect to this assumption. A constant depreciation rate of 15 percent would yield an economic value of $11.2 billion on January 1, 1991. That value is close to the rate base. Under that assumption, our estimate of the cumulative gains from price caps is $1.8 billion.